COMPUTING AND VALIDATING TRUNK TRANSVERSE SURFACE AREA EQUATIONS TO ASSESS SWIMMER'S DRAG FORCE

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INTRODUCTION

A couple of methods to assess drag force (i.e., computer fluid dynamics and velocity perturbation method) need to include in the data input the trunk transverse surface area (TTSA). TTSA is measured with a planimeter, on screen measure area software of plane 2D digital images or body scan. However the data collection and its treatment are somewhat time consuming and/or expensive. Therefore, most of the times practitioners and researchers estimate TTSA based on some selected anthropometrical variables. Clarys (1979) suggested a TTSA estimation equation based in the subject's body mass and height (R^2 = 0.50):

$$TTSA = 6.9256 \cdot BM + 3.5043 \cdot H - 377.156 \quad (1)$$

Where *TTSA* is the trunk transverse surface area in [cm^2], *BM* is the body mass in [kg] and *H* is the height in [cm].

Although the huge applicability and interest that this estimation equation have, because author described it in a review paper some useful information's were not reported or done with less detail than in an original research paper (e.g., sample size, sample gender, statistical power, data validation procedures, etc). Add to this, equation 2 is on regular basis used to assess drag force in children (e.g., Kjendlie and Stallman, 2008; Marinho et al., 2010) and adult swimmers (e.g., Kolmogorov and Duplischeva, 1992), male and female subjects (e.g., Kolmogorv et al., 2000; Toussaint et al., 2004) without a clear knowledge of the good-of-fit of the model to different cohort groups. Moreover, the research was performed in the seventies. Anthropometrical characteristics of the 70's swimmers it is not the same of the XXI century ones.

The aim of this study was to compute and validate estimation equations for the (TTSA) in order to be used assessing the swimmer's drag force in both genders. It was hypothesized that it is possible to compute accurate and valid equations to estimate TTSA for male and female swimmers in a broad range of ages.

METHODS

Total sample was composed of 264 subjects (152 males and 112 females). All subjects were competitive swimmers participating on regular basis on regional and/or national and/or international level competitions. Swimmers ages ranged between 10-32 years old for male subjects and 09-27 years old for female ones (fig 1).

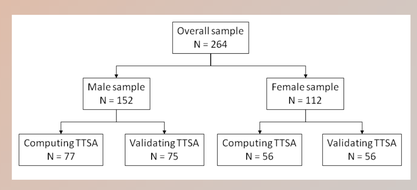

Figure 1. The split of overall sample to compute and validate the trunk transverse surface area (TTSA).

Swimmers were photographed in the transverse plane from above, on land, in the upright and hydrodynamic position. The TSA was measured from the swimmer's photo with one specific software (Udruler, AVP-Soft). Procedures included: (i) scale calibration; (ii) manual digitalization of the transverse trunk perimeter; (iii) output and recording of the TTSA value (fig 2).

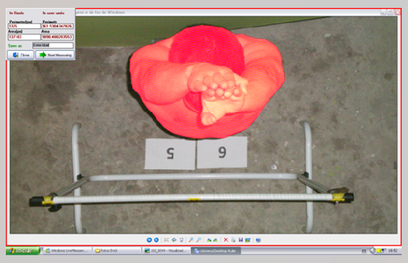

Figure 2. Software's output to measure the trunk transverse surface area (TTSA).

It was also measured the height (SECA, 242, Hamburg, Germany), body mass (SECA, 884, Hamburg, Germany), biacromial diameter (BCD), chest sagital diamameter (CSD) with a sliding calliper (Campbell, 20, RossCraft, Canada) and the chest perimeter (CP) with a flexible anthropometrical tape (RossCraft, Canada).

TTSA estimation equations was made based on stepwise multiple regression models from the selected anthropometrical variables. Validation was made: (i) comparing mean TSA assessed and the TSA estimated with the equations previously developed using paired Student's t-test; (ii) computing linear regression model between TSA assessed and estimated and; (iii) Bland-Altman analysis between assessed and estimated TSA.

RESULTS AND DISCUSSION

Table 1 presents the descriptive statistics for all selected anthropometrical variables selected, according to genders group.

For male gender, the final model ($F_{2.75}$ = 17.143; $p < 0.001$) included the CP ($t = 2.963$; $p < 0.001$) and the CSD ($t = 2.333$; $p = 0.02$) in order to predict the TTSA. The equation was (R^2 = 0.32; Ra^2 = 0.30; s = 158.93; $p < 0.01$):

$$TTSA = 6.662 \cdot CP + 17.019 \cdot CSD - 210.708 \quad (2)$$

For the female gender, the final model ($F_{2.53}$ = -12.871. $p < 0.001$) include as well the CP ($t = 3.760$; $p < 0.001$) and the CSD ($t = 2.837$; $p = 0.01$). The TTSA estimation equation was (R^2 = 0.34; Ra^2 = 0.31; s = 119.22; $p < 0.01$):

$$TTSA = 7.002 \cdot CP + 15.382 \cdot CSD - 255.70 \quad (3)$$

RESULTS AND DISCUSSION

Figure 3 presents the comparison of mean data, scatter gram and Bland Altman plots between assessed and estimated TTSA based on equations 2 and 3 for male and female genders, respectively.

Mean data between assessed and estimated TTSA was non-significant. The coefficients of determination between assessed versus estimated TTSA ranged between moderate and high relationships . The cut-off values adopted for the Bland Altman Plots (i.e., less than 80 % of the plots beyond the +/- 1.96 SD agree limits)were accomplished.

Table 1. Anthropometrical characterization of male (M) and female (F) subjects for the body mass (BM), height (H), biacromial diameter (BCD), chest sagital diameter (CSD), chest perimeter (CP) and measured trunk transverse surface area (TTSA)

	BM [kg]		H [cm]		BCD [cm]		CSD [cm]		CP [cm]		TTSA [cm^2]	
	M	F	M	F	M	F	M	F	M	F	M	F
Mean	63.61	50.04	169.41	157.46	35.41	33.13	22.43	21.57	86.90	78.08	747.46	634.23
1 SD	15.10	10.04	12.12	9.37	5.07	4.85	3.00	2.85	9.31	8.41	184.59	144.56
Minimum	28.00	27.80	134.00	133.00	19.90	24.20	11.50	15.50	61.50	64.00	373.59	327.21
Maximum	108.60	72.20	189.00	178.00	50.50	44.00	31.00	28.10	112.00	97.00	1371.00	1125.20
CV	23.74	20.06	7.15	5.95	14.32	14.64	13.37	13.21	10.71	10.77	24.70	22.79

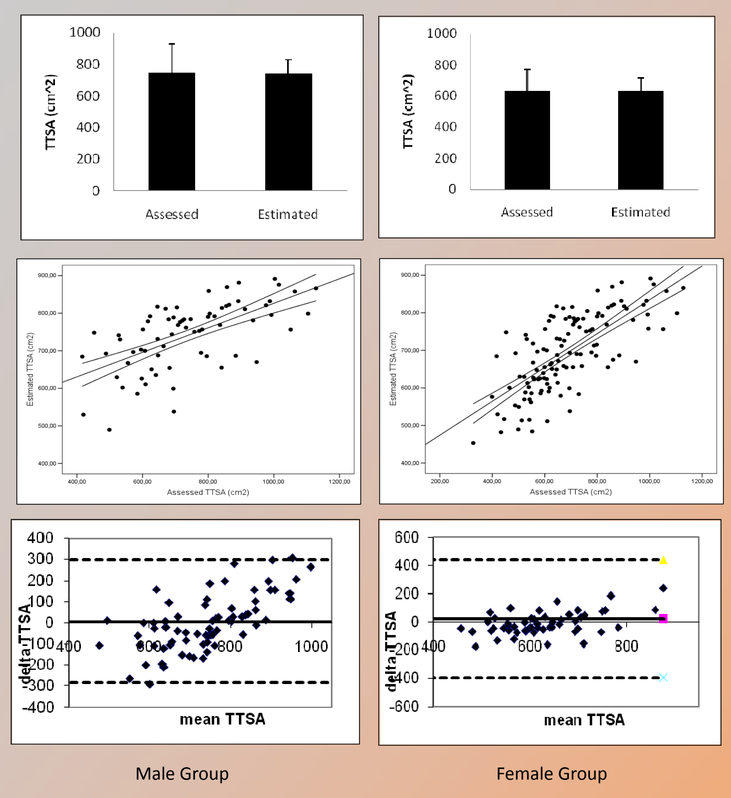

Figure 3. Comparison of mean data, scatter gram and Bland Altman plots between assessed and estimated trunk transverse surface areas (TTSA).

CONCLUSION

The computed TTSA equations based on the CP and CSD can be considered as valid to assess drag force in both genders in a broad range of ages from children to young adults.

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